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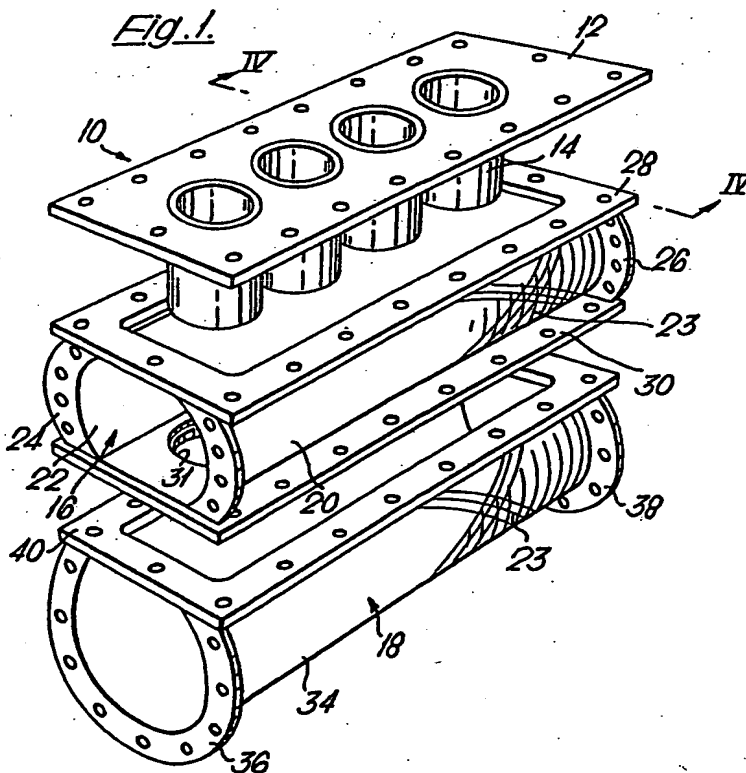
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None

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F1B  
F1W  
B8G

**(54) An engine including a fibre reinforced body**

(57) An engine block 16 or a sump 18 has bowed sides 20, 22 in transverse section constructed essentially from fibre reinforced plastics material, in which the fibres have been incorporated in the plastics material by a filament winding technique. The sides 20, 22 might be arcuate, or of multi-sided rectilinear form with the fibres wound in geodetic paths. Longitudinal and end plates of press-moulded fibre reinforced resin are secured by resin to the block and sump.



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Fig. 1.

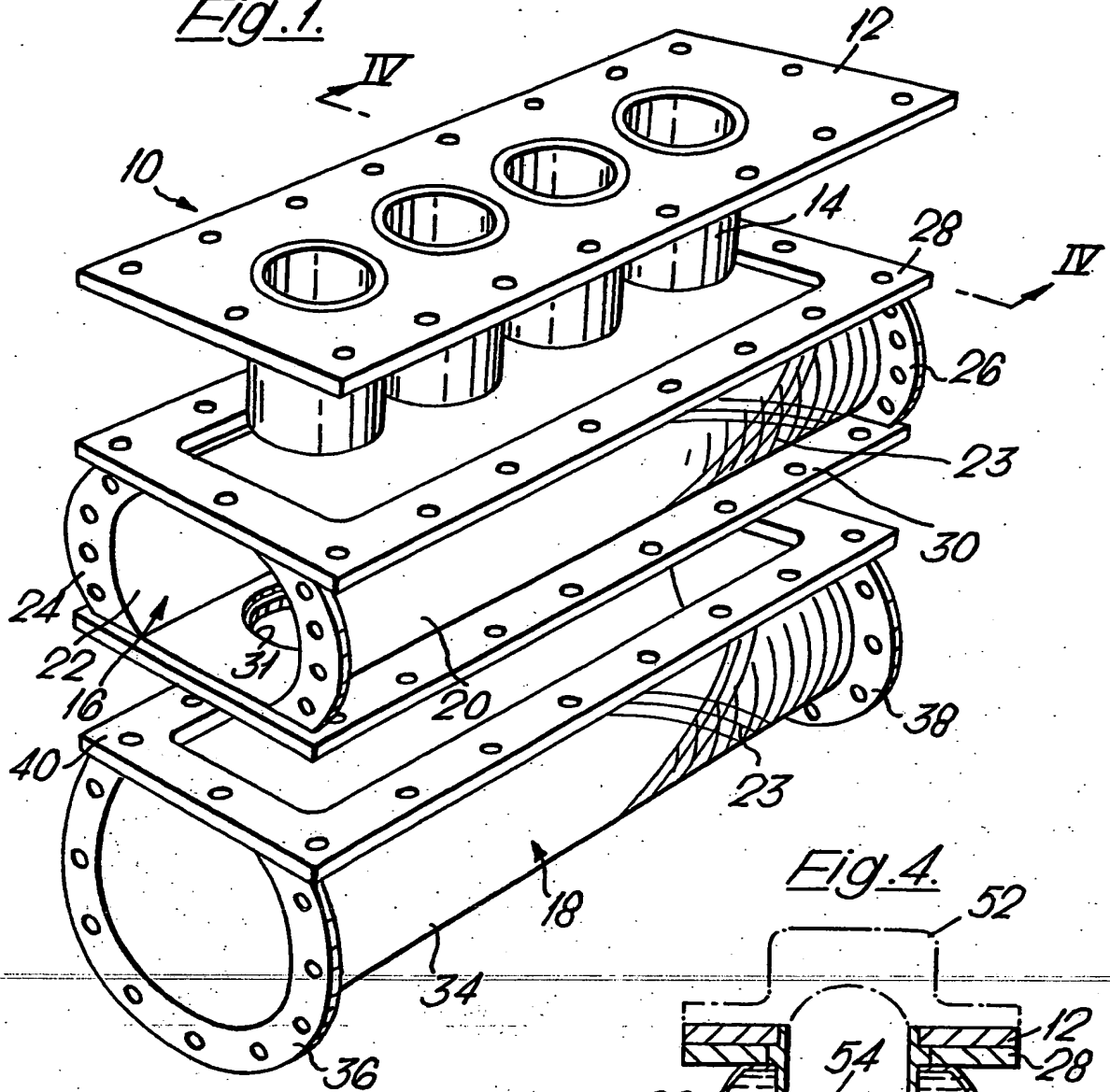


Fig. 4.

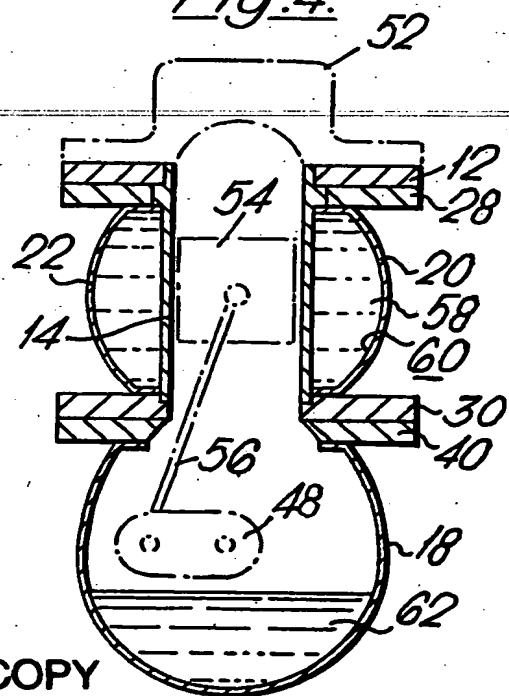


Fig. 2.

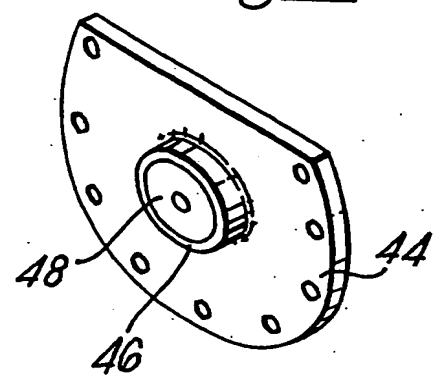


Fig. 3.

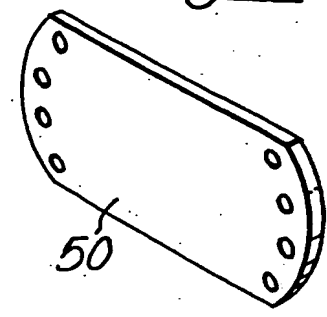
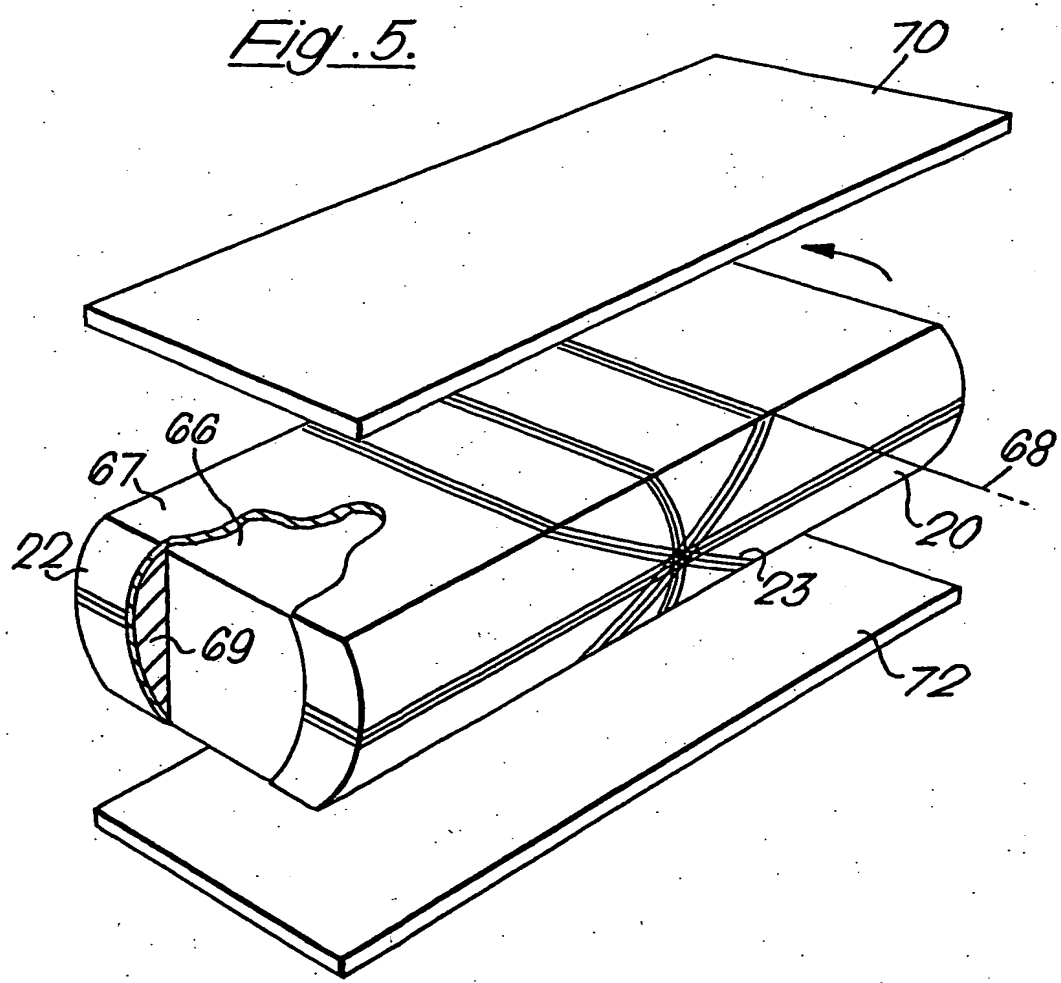


Fig. 5.



## SPECIFICATION

## An engine

- 5 This invention relates to engines, and more particularly but not exclusively, to internal combustion engines. 5  
According to one aspect of the present invention, there is provided an engine having a body portion in which the body portion at the sides thereof is at least in part of bowed form in transverse section and comprises a plastics material reinforced by fibres extending along substantially geodetic paths.
- 10 The body portion might comprise an engine block and/or a crankcase portion of the engine, and the 10  
crankcase portion might be integral with a sump portion of the engine.  
The bowed form is conveniently defined by part-cylindrical said sides extending along the engine.  
Alternatively, the bowed form might be defined by a multi-sided element.
- 15 In another aspect, the invention provides a method of manufacturing a body portion of an engine, the 15  
body portion being at the sides thereof at least in part of bowed form in transverse section, the method comprising, winding resin impregnated fibres about a former to provide a layer on the former, curing the resin in the layer, and removing redundant parts of the layer.
- 20 Preferably, the former is of truncated form, and a fibre reinforced plastics plate member may be affixed to 20  
the layer at the or each truncation of the former. The former might be of truncated cylindrical form, or of multisided rectilinear shape, to produce the bowed form of the body portion. Conveniently, a fibre reinforced plastics end member may be affixed to at least one end of the layer, and the plate member and/or the end member may be affixed either before or after the resin of the layer has been cured. Part of the plate member and/or the end member may be removed with the redundant parts of the layer, or the plate member and/or the end member may be preformed.
- 25 The fibres may be wound such that at least some of the fibres have different helix angles relative to the 25  
longitudinal axis of the body portion, desirably to define a multiplicity of diagonal geodetic constructions. Some of the fibres might be wound in one diagonal geodetic construction, other said fibres might be wound in another diagonal geodetic construction, and so forth, and some of the geodetic constructions might be longitudinally displaced with respect to each other. Some said fibres might extend substantially circumferentially at a helix angle approaching 90°C. The fibres of adjacent geodetic constructions might be 30  
interweaved or interlaced, or might form adjacent shell or wave windings.
- The invention also includes an engine having a body portion made by the method of the invention, and further includes a self-propelled vehicle arranged to be driven by the engine of the invention.
- The invention will now be further described by way of example only with reference to the accompanying drawings, in which:-
- 35 *Figure 1* shows an exploded, perspective representation of part of an internal combustion engine; 35  
*Figures 2 and 3* show perspective views of components of the engine part of *Figure 1*;  
*Figure 4* shows a diagrammatic representation on the line IV-IV of *Figure 1*, and  
*Figure 5* shows an exploded, perspective representation of a stage in the manufacture of the engine part of *Figure 1*.
- 40 Referring now to *Figure 1*, part of an internal combustion engine 10 is shown, and comprises a metal top 40  
plate 12 from which metal cylinder liners 14 depend, and an engine block 16, and a sump 18, secured together by bolts (not shown). The engine block 16 has arcuate bowed sides 20, 22, of fibre reinforced epoxy resin in which at least some of the fibres form a diagonal geodetic construction 23. Truncated end flanges 24, 26 and an upper plate 28 and a lower plate 30 with apertures 31 for the liners 14, all of press-moulded glass 45  
fibre reinforced epoxy resin construction, are affixed to the arcuate sides 20, 22 using the matrix epoxy resin or a proprietary epoxide adhesive such as Permabond Type ESP 105, supplied by: Permabond Adhesives Limited, Eastleigh, Hampshire, England. The sump 18 is constructed in a similar manner to the engine block 16, having a part-cylindrical body 34 of fibre reinforced epoxy resin to which end flanges 36, 38 and an upper flange 40 of press-moulded glass fibre reinforced epoxy resin are affixed. An end plate 44 (see *Figure 2*) 50  
having a bearing boss 46 in which a crankshaft 48 locates, is secured by bolts (not shown) to each of the end flanges 36, 38, and an end panel 50 (see *Figure 3*) is secured by bolts (not shown) to each of the end flanges 24, 26. Additional bearers (not shown) for crankshaft bearings are affixed inside the sump 18, and might comprise fibre reinforced plastics material, or metal. The end plates 44 and the end panels 50 may be of fibre (e.g. glass or carbon) reinforced epoxy resin or might comprise a light metal alloy. As shown schematically 55  
in *Figure 4* and in broken line, a conventional cylinder head 52 (the tappets, valve stems, etc. being omitted for clarity) is secured to the top plate 12, and a piston member 54 locates in each in each liner 14 where it is connected by a rod 56 to the crankshaft 48. A coolant 58 circulates in a space 60 about the liners 14, sealing means (not shown) being located between the liners 14 and the lower plate 30, and a liquid lubricant 62 collects in the sump 18.
- 60 The use of other conventional components, such as an oil pump, cooling pump, and sealing members, etc. 60  
associated with an internal combustion engine may be inferred although not shown in *Figures 1* to *4*, and it will be understood that when metal components have to locate in the plastics material, appropriate threaded inserts or bushes to receive these components may be moulded in situ in the plastics material.
- In use the engine 10 performs as a conventional internal combustion engine, but because of the use of 65  
fibre reinforced plastics material and the manner in which the fibres have been applied, the engine 10 is 65

relatively light but nonetheless is remarkably strong and rigid. Another advantage of the use of fibre reinforced plastics material is that such materials have good damping characteristics with regard to mechanical vibrations so that, in comparison with an all-metal engine, the fibre reinforced plastics-based engine should produce less noise and fewer vibrations. In this respect, some modification of the shape of the engine might take place in order to optimise the sound damping properties of the engine.

The angular alignments of the fibres in the arcuate sides 20, 22 and the sump 18 are selected to meet particular stress conditions and directions. Thus, in the arcuate sides 20, 22, some of the fibres may extend in a substantially circumferential direction to resist the load imposed on the engine block 16 by the piston member 54, some of the fibres may extend at a relatively low helix angle with the longitudinal axis of the arcuate sides 20, 22 to resist longitudinal loads on the engine block 16, whilst some of the fibres at an intermediate helical angle may resist twisting from torsional loads on the engine block 16 and in effect produce a multiplicity of diagonal geodetic constructions.

The fibres of the arcuate sides 20, 22 are applied by a filament winding technique using a former provided by a mandrel shaped to produce the curvature required. In Figure 5 a truncated mandrel 66 for use in a conventional filament winding machine is shown, to produce the arcuate sides 20, 22. A continuous, epoxy resin impregnated filament 68 (glass fibres or carbon fibres) is wound about the mandrel 66, by rotation of the mandrel 66, at selected helix angles, for example to include a substantially circumferential winding and windings forming a multiplicity of diagonal geodetic constructions 23, to form a layer 67, only a few windings at each selected angle being shown as exemplifications. Some of the geodetic constructions 23 are displaced longitudinally with respect to other geodetic constructions 23, and the filament 68 may be wound to provide interweaving or interlacing of the windings, or alternatively to produce shell or wave windings. It will be understood that by the use of alternative starts for the windings, the filaments 68 of longitudinally adjacent windings are arranged in close spaced or contiguous relationship. To facilitate the winding operation, removable domed end caps 69 may be attached to the ends of the mandrel 66. After completion of the winding, press-moulded fibre reinforced plates 70, 72 are affixed to the top and the bottom respectively of the layer 67 either before or after curing of the resin of the layer 67. The end flanges 24, 26 (not shown in Figure 5) are then affixed to the cured layer 67 after removal by machining of the end portions of the layer 67 with the removal of the domed end caps 69, and the whole assembly is machined to produce the engine block 16.

The resin impregnated filaments 68 might comprise:

(a) *Glass fibres* in the form of continuous rovings made from types E or R glass by a number of manufacturers with a variety of filament diameters, Tex values (weight of roving in gms per 100m) and surface finishes. An example is Type 051 L, 1200 Tex produced by Silenka Limited of Holland.

(b) *Carbon fibres* in the form of continuous rovings or tows. Fibres are available from a number of manufacturers in tows containing 1000, 3000, 6000 and 12,000 filaments per tow, and in various grades relating to the level of fibre strength and modulus. An example is Type XAS fibre available from Courtaulds Limited of Coventry, England.

(c) *Resins* typically of the epoxide type, but may also be of the polyester, phenolic or polyimide varieties provided that they have a sufficiently low viscosity and an adequate 'pot life', to enable winding to be completed before gelation occurs. A typical epoxide system is Ciba-Geigy's MY750 resin mixed with HY906 hardener and DY062 accelerator in proportions 100/90/1 (by weight) respectively. A typical cure schedule for such a resin is 2 hours at 120°C followed by 5 hours at 165°C.

Apart from the filament wound arcuate sides 20, 22, and sump 18, the fibre reinforced plastics material components might be manufactured by:-

(a) press-moulding laminates composed of woven rovings (fabrics) of glass or carbon fibres impregnated with resins of the type described above.

(b) press-moulding with sheet moulding compounds (SMC's). These compounds are specially formulated to flow readily when heated in a mould so as to fill all the mould cavities, and then to undergo gelation and cure. Sheet moulding compounds can take a variety of forms:-

(i) approximately equal proportions of chopped glass fibres ~25mm long, polyester resin, and inert, inorganic filler (calcium carbonate, talc) plus thickening agents. The fibres tend to be randomly oriented within the plane of the compound which is usually formulated as a paste 5-10mm thick supported on a polymer film,

(ii) similar to (i) above but with up to 55% glass fibre at the expense of the filler content,

(iii) Higher strength compounds with a combination of continuous and chopped fibres. The continuous fibres are usually oriented in one particular direction or in tow directions at a fixed angle to each other.

Some typical properties of fibre reinforced plastics materials are:-

	Material	Density 10 kgm	V %	(Volume fraction of fibre)	Tensile Strength MPa	Tensile Modulus GPa	
5	E Glass/epoxy (uni- directional)	2.03	60		700 - 1200	45 - 55	5
10	XAS Carbon/ epoxy (uni- directional)	1.55	60		1500 - 2300	110 - 150	10
15	E glass/ epoxy (woven rovings bi- directional)		50		400	25	15
20	XAS carbon/ (Woven fabric bi- directional)		65		600	75	20
25	Glass SMC (i)		30		50 - 100	11 - 15	25
	Glass SMC (ii)		40 - 55		380 - 420	14 - 16	
30	Glass SMC (iii)		70 (50% contin- uous (50% chopped)		500	35	30

35 In order to introduce further weight saving, the cylinder head 52 might comprise fibre reinforced plastics material to a substantial extent. The liners 14 might then have an upper closure portion embedded in the cylinder head, for example of inverted egg cup form. 35

It will be understood that where the plastics material is likely to be adjacent to relatively high temperature regions, appropriate thermal insulating material (e.g. a ceramic material) should be interposed.

#### 40 CLAIMS 40

1. An engine having a body portion in which the body portion at the sides thereof is at least in part of bowed form in transverse section and comprises a plastics material reinforced by fibres extending along substantially geodetic paths.
- 45 2. An engine as claimed in Claim 1 wherein the sides of the body portion are of part cylindrical form. 45
3. An engine as claimed in Claim 1 wherein the sides of the body portion define, in transverse section, parts of a polygon.
4. A method of manufacturing a body portion of an engine, the body portion being at the sides thereof at least in part of bowed form in transverse section, the method comprising, winding resin impregnated fibres 50 about a former to provide a layer on the former, curing the resin in the layer, and removing redundant parts of the layer. 50
5. A method as claimed in Claim 4 wherein the former is of truncated form, and a fibre reinforced plastics plate member is affixed to the layer at the or each truncation of the former, either before or after the resin of the layer has been cured.
- 55 6. A method as claimed in Claim 4 or Claim 5 wherein a fibre reinforced plastics end member is affixed to at least one end of the layer, either before or after the resin of the layer has been cured. 55
7. A method as claimed in Claim 4, Claim 5 or Claim 6 wherein the fibres are wound such that at least some of the fibres have different helix angles relative to the longitudinal axis of the body portion, so as to define a multiplicity of diagonal geodetic constructions.
- 60 8. An engine substantially as hereinbefore described with reference to, and shown in, Figures 1, 2, 3 and 4 of the accompanying drawings. 60

9. A method of manufacturing a body portion of an engine substantially as hereinbefore described and with reference to, and shown in, Figure 5 of the accompanying drawings.

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